

論文の全文要約

Incremental rate of prefrontal oxygenation determines
performance speed during cognitive Stroop test
: the effect of ageing

(前頭前野酸素化ヘモグロビン濃度の増加率はストループ
認知課題の遂行速度に影響する : 加齢による変化)

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Background

Cognitive function is crucial for coping with changes in environmental contexts in daily life and usually declines with age. Cognitive performance during a task, such as visual discrimination, Erikson flanker task (working memory test), and Stroop test, diminishes in elderly people. However, the underlying mechanisms responsible for the deterioration of cognitive performance remain poorly understood. We hypothesized that an incremental rate of prefrontal oxygenation during a cognitive Stroop test decreases in progress of ageing, resulting in a slowdown of cognitive performance. To test this hypothesis, we identified, using multichannel near-infrared spectroscopy (NIRS), the characteristics of the oxygenated-hemoglobin concentration (Oxy-Hb) responses of the prefrontal cortex to both incongruent Stroop and congruent word-reading test.

Methods

Nine young (age, 23 ± 1 years; height, 165 ± 4 cm; body weight, 56 ± 4 kg) and nine elderly subjects (age, 64 ± 1 years; height, 164 ± 2 cm; body weight, 63 ± 4 kg) participated in the study. None of the young subjects had cardiovascular and autonomic diseases and took any medication. Five elderly subjects intook prescription medication for treatment of hypertension and other diseases, although all elderly subjects had no history of severe neurological disorder. We used a modified Japanese version of the Stroop test as a cognitive test, which requires attention, response inhibition, interference, and behavioral conflict resolution. The test used four kinds of words ('red', 'blue', 'green', and 'yellow'), which were displayed in a color different from the word's meaning. We used the word-reading test as a control trial for the Stroop test, in which all words were displayed in black ink. The test was performed in order to examine a difference in the total period between the cognitive task (Stroop test) and simple reaction test (word reading), which could be considered as an interference period necessary for discriminating and judging the color of a displayed word. The relative concentrations of the Oxy-Hb and deoxygenated-hemoglobin (Deoxy-Hb) at 22 sites in the bilateral prefrontal cortices were measured using the NIRS. The NIRS probes were placed over the frontal surface of the head. The three-dimensional location of each NIRS probe was determined using a magnetic space digitizer. The anatomical brain regions for the channels' coordinates were probabilistically estimated by using a MRICro. We detected three distinct subregions of the prefrontal cortical cortex (the frontopolar area, the pars triangularis Broca's area, and the dorsolateral prefrontal cortex). The Oxy-Hb response was assessed by the following three components: (1) initial slope, (2) peak amplitude, and (3) area under the Oxy-Hb curve. The initial slope of the Oxy-Hb response was determined as an incremental rate obtained from calculating a ratio between the 50% of the peak Oxy-Hb response and the time at which the

Oxy-Hb reached the 50% level. The peak Oxy-Hb response was defined as the greatest change from the baseline during a cognitive test. The area of Oxy-Hb response was defined as a product of the average Oxy-Hb response and the period of the test. Which component of the dynamic Oxy-Hb response most contributed to cognitive performance was examined by assessing the relationships with cognitive performance speed (as estimated by the 100 answers/total time period).

Results

Regarding the Stroop test, the total period was prolonged in elderly than young subjects, and the 100 answers/total period was smaller accordingly. The number of errors was greater in elderly subjects. The Stroop interference time approximately doubled in elderly as compared to young subjects. In the word-reading test, the total period and 100 answers/total period had the similar tendency as those for the Stroop test, while the number of errors was not different between the two age groups. In the Stroop test, significant increases in the Oxy-Hb response were found in both age groups at most sites, except the caudal region; the Oxy-Hb responses were greater in the rostral prefrontal cortex than the caudal prefrontal cortex in both age groups. The Deoxy-Hb at all prefrontal sites was unchanged. During the Stroop test, the initial slope of Oxy-Hb was significantly blunted in elderly compared to young subjects, whereas no or slight differences in the peak amplitude and area under the Oxy-Hb curve were detected between the two age groups. The performance speed had no significant correlation with the initial slope, peak, and area of Oxy-Hb in elderly subjects, while several channels showed a significant correlation with those in young subjects. Not only the number of channels but also the slope of linear regression line was larger when plotting the performance speed against the initial slope of the Oxy-Hb response, compared with that plotting the performance speed against the peak or area of the Oxy-Hb response. In these channels which showed a significant correlation between the performance speed and Oxy-Hb response, we found that the slopes of the regression line were larger in young subjects than those in elderly subjects. Although the Oxy-Hb increased during the word-reading test, the Oxy-Hb responses were smaller than those during the Stroop test in both age groups. The Oxy-Hb increased in most of the rostrolateral prefrontal sites, whereas the Oxy-Hb changes in the rostromedial and caudal prefrontal sites were not significant. The prefrontal distributions of the significant Oxy-Hb response were almost similar between young and elderly groups. During the word reading test, the initial slope and peak of the Oxy-Hb responses were greater in young than elderly subjects, although the area under the curve was comparable between the two groups. Only a few channels showed a significant correlation between the cognitive performance and the Oxy-Hb response in

young subjects. The slope of linear regression line for the plots of performance speed against the initial slope or peak of Oxy-Hb response during word-reading was smaller, and the intercept value of linear regression line was larger than that during Stroop test.

Limitations

Some substantial problems are involved in this study. First, the NIRS measurement was limited to the regions near the cortical surface and the rCBF changes in deeper cerebral structures could not be measured. Second, the NIRS data in the temporal cortex and occipital cortex were lacking due to a technical limitation in this study, although the rCBF in the cortical regions increased during cognitive tests. Third, the response in the prefrontal Oxy-Hb and cognitive function might be influenced by medical condition and/or taking prescription medicines in some elderly subjects, although in the present study there was no obvious difference in the physical characteristics, cognitive performance, and prefrontal oxygenation response due to the medical condition with our nine elderly subjects (five of them were taking medicines and four were not). Further experiments with more populations are needed to clarify whether the medical condition affects the prefrontal oxygenation response and cognitive performance.

Conclusion

The Oxy-Hb in the rostrolateral, but not caudal, prefrontal cortex increased during the Stroop test in both young and elderly subjects. The initial slope component, rather than the peak or area of the prefrontal Oxy-Hb response, had substantial correlation with the cognitive performance speed. The present study provided evidence that the incremental rate of prefrontal oxygenation may decrease in the progression of ageing, resulting in a decline in incongruent cognitive performance.